
Joint Group – Pollution Prevention (JG-PP) Lead Free Soldering Study EMR & SIR Test Results

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Boeing - Anaheim

Agenda

- About JG-PP
- Lead-free solder project (S1-01-EM-026)
- Electromigration (EMR) test results
- EMR test observations/recommendations
- Surface-insulation resistance (SIR) test results
- SIR test observations/recommendations
- Summary and conclusions

About JG-PP

JG-PP is a partnership between the military Services, NASA, DLA, DCMA, chartered by the JLC to reduce or eliminate HazMats or processes within the acquisition and sustainment communities. By establishing these partnerships, JG-PP addresses the common problems through shared efforts to produce joint solutions.

website at www.jgpp.com

About JG-PP (Cont.)

- **Mission**

- Reduce costs of elimination of hazardous materials in manufacturing for government acquisitions
- Maintain public references and links for environmentally friendly manufacturing processes
- Conduct projects to mitigate the use of hazardous materials in manufacturing
 - Elimination of isocyanates in aliphatic polyurethanes
 - Identification of alternatives to chromium electroplating operations
 - Selection of low-emission surface-preparation methods
 - Evaluation of solders (S1-01-EM-026)

About JG-PP (Cont.)

- **Operation**

- Identifies shared opportunities
- Facilitates partnerships
- Facilitates qualification requirements
- Reduces duplication of effort
- Reduces risk and cost

Lead-free Solder Project Number: S1-01-EM-026

- Identify and qualify lead-free solders to replace conventional tin lead solders used on circuit card and other assemblies
- Provide baseline data for use in the eventual qualification of lead-free solder in high reliability systems
- Reduce technical risk in qualifying lead free solder
- Decrease the use of leaded solder manufacturing and sustaining maintenance costs
- Reduce pollution without degrading solder quality or performance

Lead-free Solder Project Number: S1-01-EM-026 (Cont.)

- **Test plan and board design completed by TBD**
 - Stabilized tin-copper+Ni, tin-silver-copper (SAC), and tin-silver-copper-bismuth alloys selected
 - Tin-lead controls selected
 - New boards and reworked boards used
- **Test boards fabricated at Boeing-Irving facility**
- **Completed boards distributed to industry for evaluation**

Lead-free Solder Project Number: S1-01-EM-026 (Cont.)

- **Boeing-Anaheim test plan**
 - Perform EMR IPC-TM-650 2.6.14.1 (596 hours total)
 - Precondition 65°C 85%RH (96 hrs, unbiased)
 - Test at 65°C 85%RH (500 hrs, 10 volts DC)
 - IPC-B-25A Test Vehicles (six boards each)
 - Reflow solder alloy
 - SnAgCu and flux (Kester) rosin
 - SnAgCuBi and no-clean flux (CL30-8467)
 - SnPb and Rosin flux (Kester) Rosin (control)
 - Wave-solder alloy
 - SnCu and no-clean flux (SN100C)
 - SnAgCu and Rosin flux (Kester)
 - SnPb and Rosin flux (R244)
 - No solder paste, bare copper finish processed simulated reflow and wave solder and cleaning procedures only

Lead-free Solder Project Number: S1-01-EM-026 (Cont.)

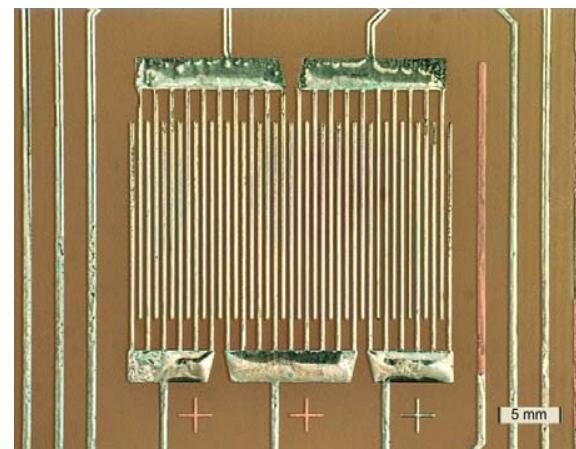
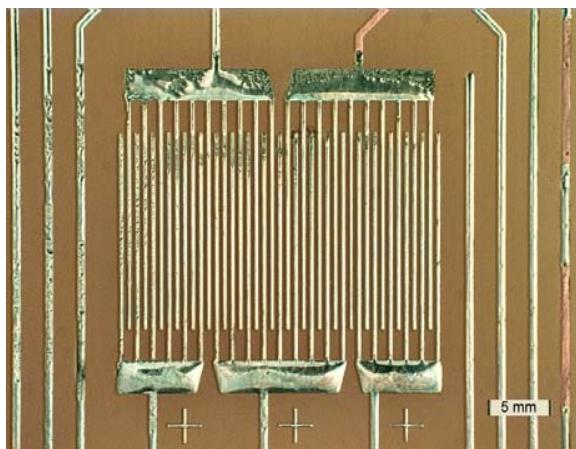
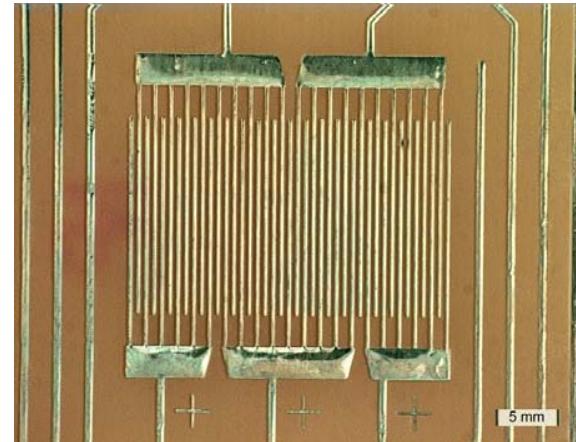
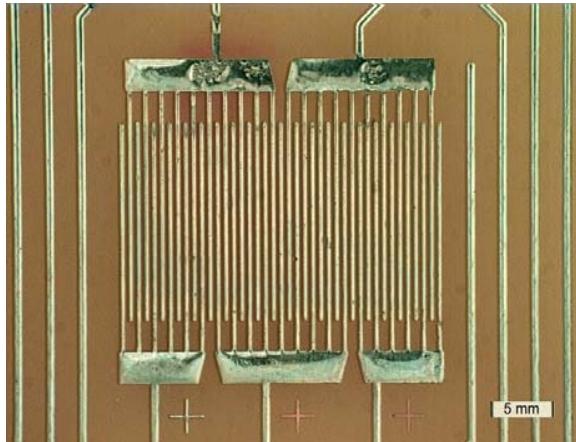
- **Boeing-Anaheim test plan**
 - Perform SIR per IPC-TM-650 2.6.3.3
 - 85 ° C, 85%RH, 100 VDC, 168 hrs
 - IPC-B-25A Test Vehicles (six boards each)
 - Reflow solder
 - SnAgCu solder alloy and no-clean flux (GRN360K)
 - SnAgCuBi solder alloy and no-clean flux (CL30-8467)
 - SnPb solder alloy and flux (Kester) Rosin
 - Wave solder
 - SnCu and no-clean flux (SN100C)
 - SnAgCu and Rosin flux (Kester)
 - SnPb and Rosin flux (R244)
 - No solder paste, bare copper finish processed simulated reflow and wave solder and cleaning procedures only

Run # 1 EMR Test Results

Solder	Serial Number	Electromigration Test Data (Ohm)												Dendrites (Y/N)*
		Initial	After 96 hour stabilization bake	50 hours 85 % RH/ 85°C	100 hours 85 % RH/ 85°C	150 hours 85 % RH/ 85°C	200 hours 85 % RH/ 85°C	250 hours 85 % RH/ 85°C	300 hours 85 % RH/ 85°C	350 hours 85 % RH/ 85°C	400 hours 85 % RH/ 85°C	450 hours 85 % RH/ 85°C	500 hours 85 % RH/ 85°C	
SnAgCu	1	1.4 x 10 ¹¹	6.6 x 10 ⁸	2.9 x 10 ⁸	3.4 x 10 ⁸	3.0 x 10 ⁶	3.2 x 10 ⁸	1.5 x 10 ⁸	1.5 x 10 ⁸	2.5 x 10 ⁷	1.0 x 10 ⁸	2.6 x 10 ⁷	2.0 x 10 ¹⁰	Y
	2	2.0 x 10 ¹¹	1.0 x 10 ⁹	5.8 x 10 ⁸	5.5 x 10 ⁸	5.4 x 10 ⁸	5.8 x 10 ⁸	3.1 x 10 ⁸	3.1 x 10 ⁸	2.2 x 10 ⁸	5.3 x 10 ⁷	6.2 x 10 ⁷	8.5 x 10 ⁴	N
	3	9.0 x 10 ¹⁰	3.0 x 10 ⁸	1.5 x 10 ⁸	1.8 x 10 ⁸	1.7 x 10 ⁸	2.0 x 10 ⁸	1.2 x 10 ⁸	1.2 x 10 ⁸	1.0 x 10 ⁸	1.2 x 10 ⁸	1.2 x 10 ⁸	3.3 x 10 ⁴	N
	4	5.5 x 10 ⁹	8.8 x 10 ⁶	3.1 x 10 ⁶	2.8 x 10 ⁶	3.1 x 10 ⁶	3.1 x 10 ⁶	2.0 x 10 ⁶	2.1 x 10 ⁶	2.3 x 10 ⁶	2.3 x 10 ⁶	2.4 x 10 ⁶	3.8 x 10 ⁸	N
	5	9.5 x 10 ¹⁰	2.8 x 10 ⁸	1.2 x 10 ⁸	1.1 x 10 ⁸	1.0 x 10 ⁸	1.0 x 10 ⁷	6.2 x 10 ⁷	5.5 x 10 ⁷	4.8 x 10 ⁷	5.1 x 10 ⁷	5.5 x 10 ⁷	1.1 x 10 ¹⁰	Y
	6	7.5 x 10 ¹⁰	2.8 x 10 ⁸	1.2 x 10 ⁸	1.1 x 10 ⁸	1.0 x 10 ⁸	1.0 x 10 ⁸	6.2 x 10 ⁷	5.5 x 10 ⁷	4.8 x 10 ⁷	5.1 x 10 ⁷	5.5 x 10 ⁷	1.1 x 10 ¹⁰	N
None (Bare copper – no bake)	1	2.1 x 10 ¹¹	3.2 x 10 ⁹	4.2 x 10 ⁹	1.8 x 10 ⁹	1.8 x 10 ⁹	1.7 x 10 ⁹	4.0 x 10 ⁹	8.5 x 10 ⁸	6.4 x 10 ⁸	6.2 x 10 ⁸	7.5 x 10 ⁸	8.5 x 10 ¹⁰	N
	2	2.1 x 10 ¹¹	2.1 x 10 ⁹	2.8 x 10 ⁹	5.9 x 10 ⁹	3.8 x 10 ⁹	5.2 x 10 ⁹	2.3 x 10 ⁹	2.4 x 10 ⁹	1.4 x 10 ⁹	7.6 x 10 ⁷	1.2 x 10 ⁸	5.5 x 10 ⁹	Y
	3	2.0 x 10 ¹¹	2.8 x 10 ⁹	6.2 x 10 ⁸	1.5 x 10 ⁹	9.0 x 10 ⁸	1.7 x 10 ⁹	9.0 x 10 ⁷	8.5 x 10 ⁶	8.5 x 10 ⁷	4.2 x 10 ⁷	3.0 x 10 ⁷	6.5 x 10 ⁹	Y
	4	2.1 x 10 ¹¹	4.3 x 10 ⁹	5.8 x 10 ⁹	5.5 x 10 ⁹	3.6 x 10 ⁹	6.0 x 10 ⁹	4.0 x 10 ⁷	6.5 x 10 ⁸	1.0 x 10 ⁸	2.8 x 10 ⁷	6.5 x 10 ⁶	5.0 x 10 ⁸	Y
	5	2.0 x 10 ¹¹	1.8 x 10 ⁹	2.2 x 10 ⁹	2.6 x 10 ⁹	1.7 x 10 ⁹	3.1 x 10 ⁹	1.3 x 10 ⁷	4.3 x 10 ⁷	8.0 x 10 ⁷	1.0 x 10 ⁷	3.6 x 10 ⁶	2.3 x 10 ⁸	Y
Bare copper control (baked)	1	1.6 x 10 ¹¹	2.8 x 10 ⁹	2.4 x 10 ⁶	6.5 x 10 ⁶	5.5 x 10 ⁹	7.4 x 10 ⁹	4.4 x 10 ⁹	3.5 x 10 ⁸	2.6 x 10 ⁸	1.2 x 10 ⁹	1.4 x 10 ⁹	1.2 x 10 ⁹	Y
	2	2.3 x 10 ¹¹	1.2 x 10 ⁸	8.2 x 10 ⁹	1.0 x 10 ⁶	<1.0 x 10 ⁶	1.2 x 10 ⁶	1.0 x 10 ⁶	1.3 x 10 ⁶	<1.0 x 10 ⁶	1.7 x 10 ⁶	1.9 x 10 ⁶	1.0 x 10 ⁸	Y
	3	2.2 x 10 ¹¹	1.0 x 10 ¹⁰	8.0 x 10 ⁹	8.0 x 10 ⁹	5.7 x 10 ⁶	1.7 x 10 ⁷	1.7 x 10 ⁷	2.4 x 10 ⁷	6.5 x 10 ⁶	2.4 x 10 ⁷	2.2 x 10 ⁷	1.0 x 10 ¹²	N
	4	2.3 x 10 ¹¹	1.2 x 10 ¹⁰	5.9 x 10 ⁹	2.8 x 10 ⁶	1.8 x 10 ⁸	1.7 x 10 ⁸	6.2 x 10 ⁷	1.1 x 10 ⁸	5.5 x 10 ⁸	9.0 x 10 ⁷	9.0 x 10 ⁷	7.5 x 10 ⁸	Y
	5	2.3 x 10 ¹¹	1.6 x 10 ¹¹	4.7 x 10 ⁹	1.8 x 10 ⁸	5.3 x 10 ⁶	2.7 x 10 ⁷	2.0 x 10 ⁷	2.1 x 10 ⁷	6.5 x 10 ⁶	2.9 x 10 ⁷	8.4 x 10 ⁷	1.2 x 10 ¹⁰	N

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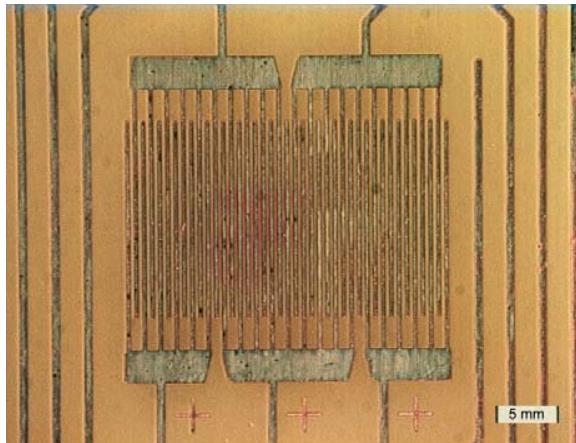
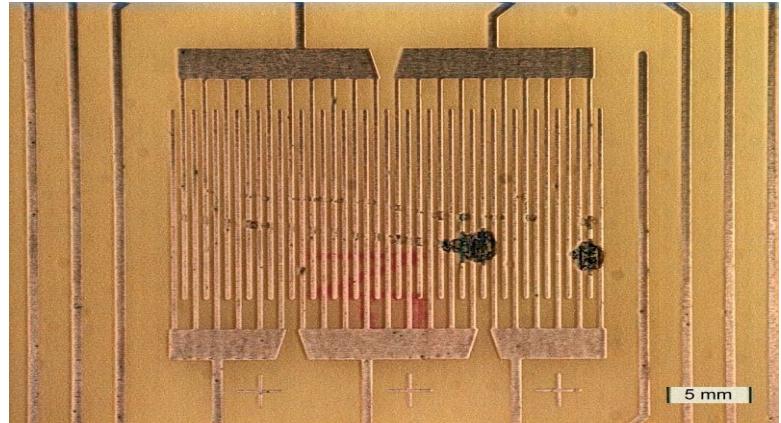
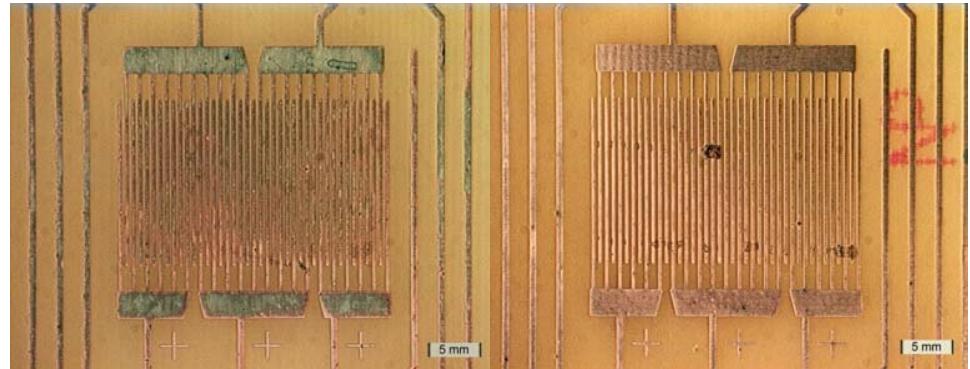
Run #1 EMR Test Results (Cont.)



Tin Silver Copper, reflow - small black dendrites
not as shiny as tin lead

Run #1 EMR Test Results (Cont.)

- Copper controls (no bake) showed tarnish but no dendritic growth or contamination
- Copper controls (bake) showed over-induced contamination but no growth (see pictures)



Run #2 EMR Test Results

Solder /Flux	Serial Number	Electromigration Test Data (Ohm)												Dendrites (Y/N)*
		Initial	After 96 hour stabilization bake	50 hours 85 % RH/ 85°C	100 hours 85 % RH/ 85°C	150 hours 85 % RH/ 85°C	200 hours 85 % RH/ 85°C	250 hours 85 % RH/ 85°C	300 hours 85 % RH/ 85°C	350 hours 85 % RH/ 85°C	400 hours 85 % RH/ 85°C	450 hours 85 % RH/ 85°C	500 hours 85 % RH/ 85°C	
Sn37Pb/Kester-ultrapure	1	1.0 x 10 ¹¹	7.0 x 10 ⁷	1.2 x 10 ⁸	1.1 x 10 ⁸	1.4 x 10 ⁸	2.1 x 10 ⁸	7.0 x 10 ⁷	1.0 x 10 ⁷	6.0 x 10 ⁷	4.1 x 10 ⁷	5.5 x 10 ⁷	2.6 x 10 ⁸	N
	2	2.3 x 10 ¹¹	1.1 x 10 ⁹	8.5 x 10 ⁸	7.2 x 10 ⁸	7.5 x 10 ⁸	1.1 x 10 ⁹	1.3 x 10 ⁹	1.3 x 10 ⁹	1.3 x 10 ⁹	1.4 x 10 ⁹	1.4 x 10 ⁹	8.5 x 10 ⁹	N
	3	2.4 x 10 ¹¹	1.8 x 10 ⁹	7.2 x 10 ⁹	1.0 x 10 ¹⁰	7.2 x 10 ¹²	3.8 x 10 ¹²	1.2 x 10 ¹²	4.5 x 10 ¹²	7.5 x 10 ¹²	3.0 x 10 ¹³	1.1 x 10 ¹³	7.0 x 10 ¹²	N
	4	3.6 x 10 ¹⁰	2.6 x 10 ⁷	4.6 x 10 ⁷	5.6 x 10 ⁷	6.7 x 10 ⁷	6.5 x 10 ⁷	6.5 x 10 ⁷	7.2 x 10 ⁷	6.5 x 10 ⁷	6.3 x 10 ⁷	5.1 x 10 ⁸	5.1 x 10 ⁸	N
	5	2.6 x 10 ¹¹	2.6 x 10 ⁷	1.0 x 10 ⁸	4.2 x 10 ⁷	6.0 x 10 ⁷	4.8 x 10 ⁷	1.4 x 10 ⁷	8.5 x 10 ⁶	4.6 x 10 ⁶	5.5 x 10 ⁶	5.5 x 10 ⁶	3.0 x 10 ⁷	Y
	6	6.0 x 10 ⁷	2.3 x 10 ⁷	2.3 x 10 ⁶	<1.0 x 10 ⁶	Y								
Sn Ag Cu Bi/CL30-8457	1	1.5 x 10 ¹¹	1.3 x 10 ⁸	1.0 x 10 ⁶	6.5 x 10 ⁶	1.1 x 10 ⁷	1.4 x 10 ⁷	2.3 x 10 ⁶	5.0 x 10 ⁶	5.0 x 10 ⁶	3.4 x 10 ⁶	4.0 x 10 ⁶	4.0 x 10 ⁶	Y
	2	1.0 x 10 ¹¹	1.3 x 10 ⁸	6.5 x 10 ⁷	1.7 x 10 ⁸	2.3 x 10 ⁸	6.0 x 10 ⁶	1.1 x 10 ⁷	1.4 x 10 ⁷	9.0 x 10 ⁶	6.0 x 10 ⁶	8.5 x 10 ⁶	1.6 x 10 ⁷	Y
	3	4.1 x 10 ¹⁰	1.0 x 10 ⁸	6.0 x 10 ⁷	9.0 x 10 ⁷	1.7 x 10 ⁸	1.2 x 10 ⁷	1.8 x 10 ⁷	1.6 x 10 ⁷	2.4 x 10 ⁷	4.3 x 10 ⁷	9.5 x 10 ⁶	3.0 x 10 ⁷	N
	4	9.5 x 10 ¹⁰	8.5 x 10 ⁷	5.5 x 10 ⁶	1.9 x 10 ⁶	6.5 x 10 ⁶	1.2 x 10 ⁶	<1.0 x 10 ⁶	1.5 x 10 ⁶	<1.0 x 10 ⁶	<1.0 x 10 ⁶	<1.0 x 10 ⁶	<1.0 x 10 ⁶	Y
	5	1.4 x 10 ¹¹	1.7 x 10 ⁸	3.8 x 10 ⁸	5.1 x 10 ⁸	4.0 x 10 ⁸	4.2 x 10 ⁸	4.1 x 10 ⁸	2.4 x 10 ⁷	5.2 x 10 ⁷	1.3 x 10 ⁸	9.7 x 10 ⁷	6.5 x 10 ⁸	N
	6	3.8 x 10 ¹⁰	1.2 x 10 ⁸	2.3 x 10 ⁸	2.2 x 10 ⁷	5.5 x 10 ⁷	2.2 x 10 ⁷	3.5 x 10 ⁷	3.0 x 10 ⁷	1.9 x 10 ⁶	3.3 x 10 ⁶	3.2 x 10 ⁶	1.1 x 10 ⁷	Y
Sn Cu/SN100C	1	1.8 x 10 ¹¹	1.2 x 10 ⁷	6.5 x 10 ⁶	5.7 x 10 ⁶	5.5 x 10 ⁶	2.0 x 10 ⁷	2.2 x 10 ⁷	2.4 x 10 ⁷	2.3 x 10 ⁷	2.4 x 10 ⁷	2.4 x 10 ⁷	2.7 x 10 ⁸	N
	2	8.0 x 10 ⁹	6.5 x 10 ⁶	3.7 x 10 ⁶	2.4 x 10 ⁶	2.4 x 10 ⁶	1.5 x 10 ⁶	1.5 x 10 ⁶	1.4 x 10 ⁶	9.0 x 10 ⁶	N			
	3	1.0 x 10 ¹¹	4.5 x 10 ⁷	5.0 x 10 ⁷	4.3 x 10 ⁷	4.0 x 10 ⁷	3.5 x 10 ⁶	3.2 x 10 ⁶	3.2 x 10 ⁶	3.2 x 10 ⁶	4.7 x 10 ⁶	7.5 x 10 ⁶	8.1 x 10 ⁷	Y
	4	8.5 x 10 ⁹	9.2 x 10 ⁶	6.9 x 10 ⁶	5.5 x 10 ⁶	5.5 x 10 ⁶	3.4 x 10 ⁶	3.2 x 10 ⁶	3.0 x 10 ⁶	2.7 x 10 ⁶	2.8 x 10 ⁶	2.7 x 10 ⁶	1.5 x 10 ⁷	N
	5	1.8 x 10 ¹¹	1.2 x 10 ⁹	1.8 x 10 ⁸	1.6 x 10 ⁷	1.5 x 10 ⁸	1.1 x 10 ⁸	1.3 x 10 ⁸	9.5 x 10 ⁷	8.5 x 10 ⁶	7.8 x 10 ⁷	7.5 x 10 ⁷	5.7 x 10 ⁸	N
	6	1.4 x 10 ¹¹	7.0 x 10 ⁷	6.0 x 10 ⁷	5.3 x 10 ⁷	3.6 x 10 ⁷	3.6 x 10 ⁷	3.5 x 10 ⁷	3.0 x 10 ⁷	2.6 x 10 ⁷	2.4 x 10 ⁷	2.3 x 10 ⁷	1.7 x 10 ⁸	N

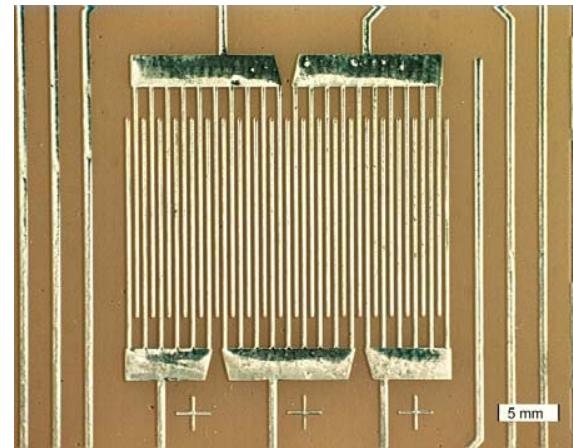
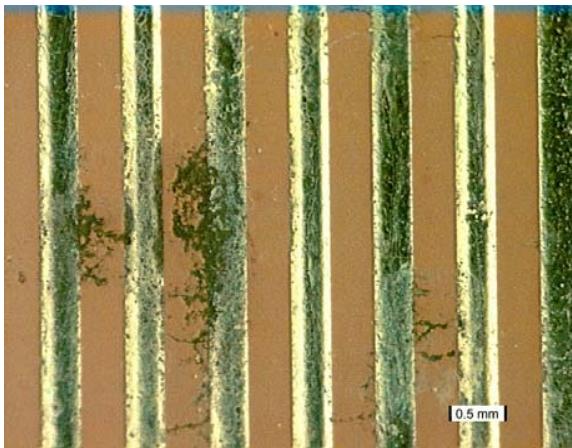
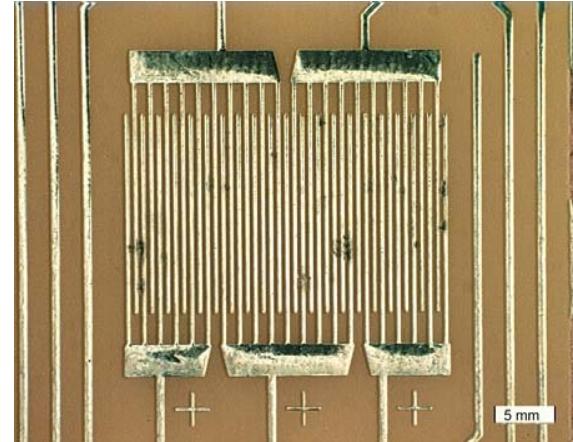
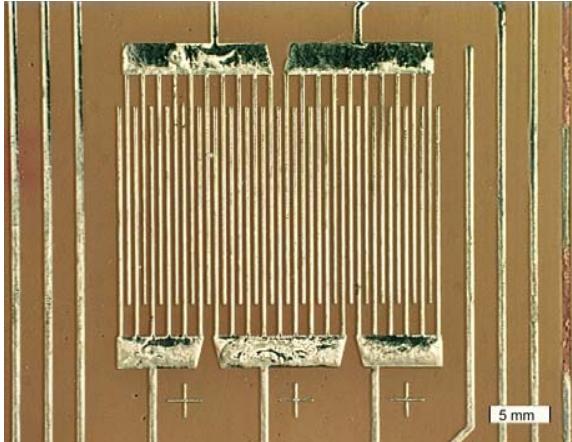
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Run #2 EMR Test Results (Cont.)

Solder /Flux	Serial Number	Electromigration Test Data (Ohm)												Dendrites (Y/N)*
		Initial	After 96 hour stabilization bake	50 hours 85 % RH/ 85°C	100 hours 85 % RH/ 85°C	150 hours 85 % RH/ 85°C	200 hours 85 % RH/ 85°C	250 hours 85 % RH/ 85°C	300 hours 85 % RH/ 85°C	350 hours 85 % RH/ 85°C	400 hours 85 % RH/ 85°C	450 hours 85 % RH/ 85°C	500 hours 85 % RH/ 85°C	
Sn37Pb/Kester-R244	1	2.6×10^{11}	3.5×10^{10}	3.8×10^{10}	3.3×10^{10}	3.3×10^{10}	3.2×10^{10}	3.2×10^{10}	3.7×10^{10}	3.2×10^{10}	3.3×10^{10}	3.3×10^{10}	1.2×10^{12}	N
	2	2.6×10^{11}	1.2×10^9	2.0×10^9	2.4×10^9	1.7×10^9	1.1×10^9	3.0×10^9	3.4×10^{10}	3.0×10^9	3.2×10^9	1.5×10^9	4.2×10^{10}	N
	3	2.4×10^{11}	9.0×10^9	1.1×10^7	1.2×10^7	2.2×10^7	9.5×10^7	6.5×10^7	3.2×10^9	5.5×10^7	4.0×10^7	6.5×10^7	1.5×10^8	N
	4	2.6×10^{11}	2.1×10^8	2.3×10^8	1.1×10^8	3.2×10^7	1.4×10^7	1.2×10^7	4.6×10^8	2.2×10^7	1.7×10^7	1.8×10^7	3.2×10^8	N
	5	2.6×10^{11}	2.2×10^8	2.8×10^8	3.8×10^8	3.2×10^8	5.7×10^8	5.0×10^8	1.9×10^7	4.0×10^8	3.6×10^8	3.1×10^8	3.0×10^9	N
	6	2.6×10^{11}	1.5×10^9	5.0×10^7	4.5×10^7	8.0×10^7	1.9×10^9	2.6×10^7	5.5×10^7	2.9×10^7	3.4×10^7	6.5×10^6	6.0×10^6	Y
Sn Ag Cu/ 7100 GNR 360 K	1	2.6×10^{11}	2.0×10^8	5.3×10^6	2.0×10^6	2.0×10^6	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	Y
	2	1.8×10^{11}	4.1×10^7	1.3×10^7	1.3×10^7	1.6×10^7	3.2×10^6	2.6×10^6	2.3×10^6	2.2×10^6	1.3×10^6	1.2×10^6	1.8×10^6	N
	3	3.2×10^{11}	1.2×10^9	7.0×10^6	1.0×10^6	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	Y
	4	2.4×10^{11}	5.8×10^8	7.5×10^6	$<1.0 \times 10^6$	1.2×10^6	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	N
	5	2.6×10^{11}	2.8×10^8	3.5×10^8	2.1×10^8	2.5×10^8	1.9×10^7	1.4×10^7	3.6×10^6	7.5×10^6	3.0×10^7	2.6×10^7	1.5×10^8	N
	6	2.4×10^{11}	3.8×10^9	1.2×10^7	7.0×10^6	7.0×10^6	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	$<1.0 \times 10^6$	Y

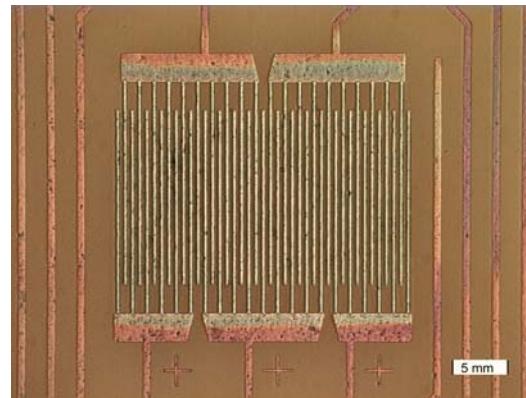
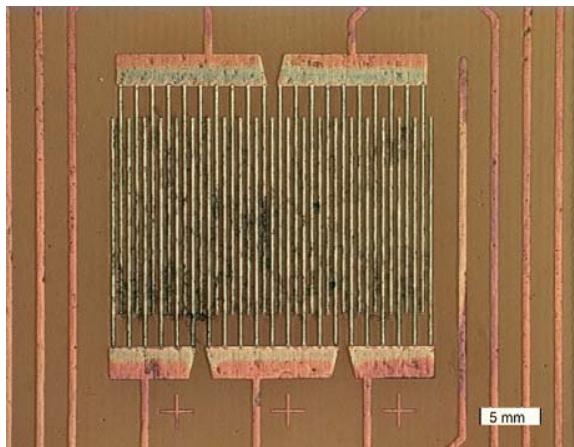
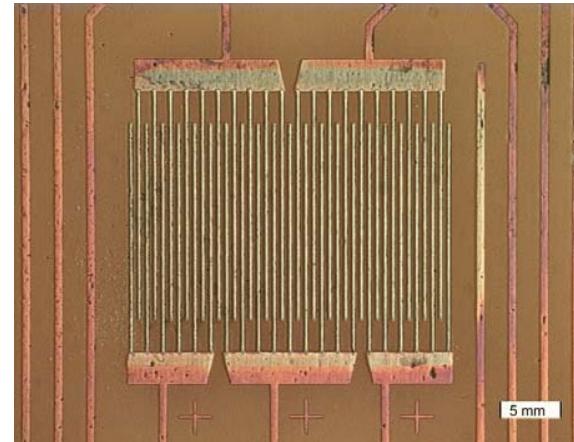
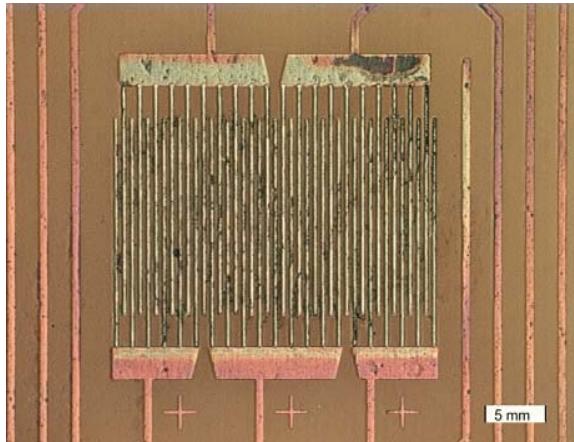
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Run #2 EMR Test Results



Tin-lead, wave solder/Kester Ultra-Pure (or **Ultrapure**) - shiny
solder black dendrites

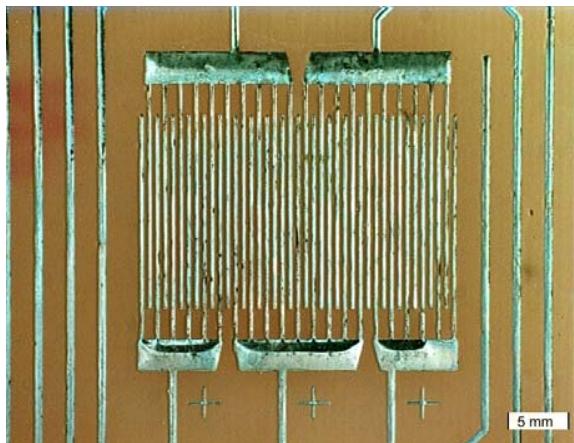
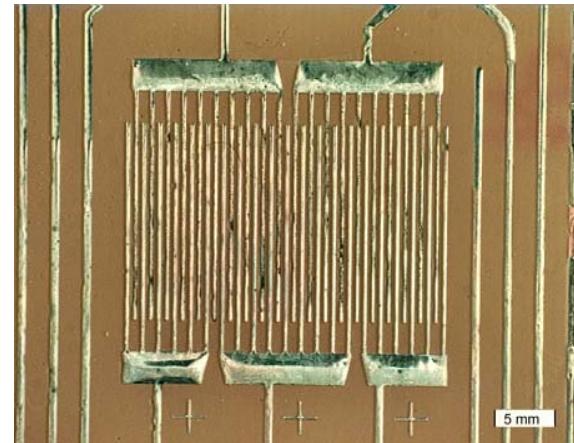
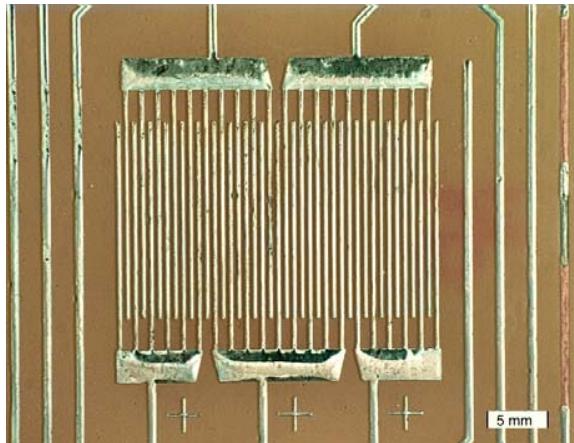
Run #2 EMR Test Results (Cont.)



Tin Silver Bismuth Copper, black solder, translucent residue, black dendrites, bare Cu

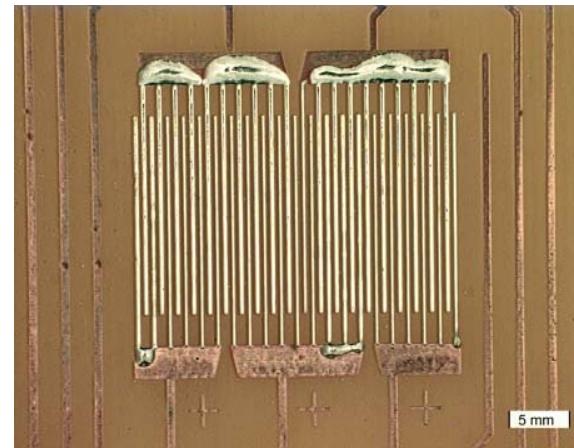
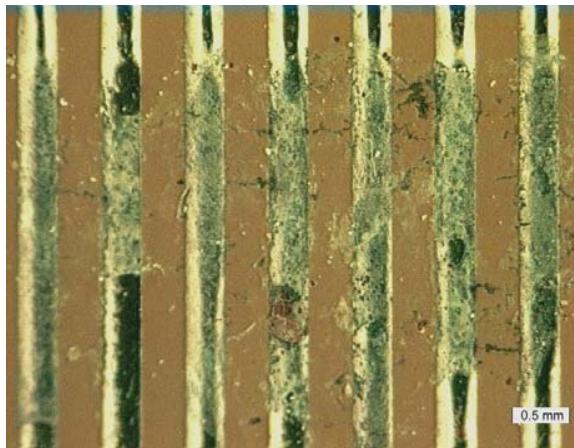
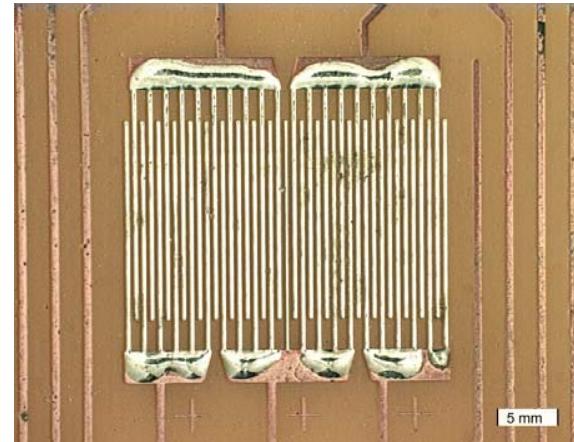
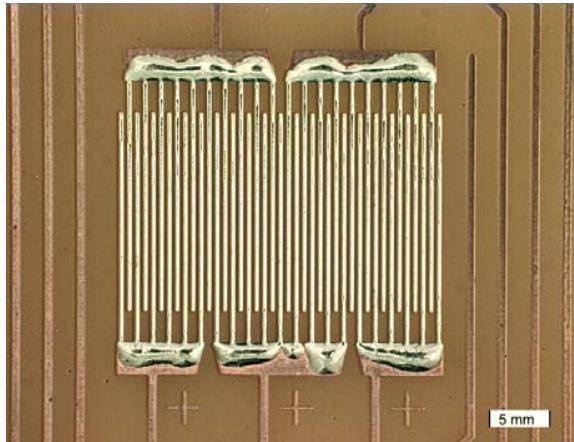
 **BOEING**

Run #2 EMR Test Results (Cont.)



Tin-copper, wave solder - black corrosion light color dendrites (no clean residues)

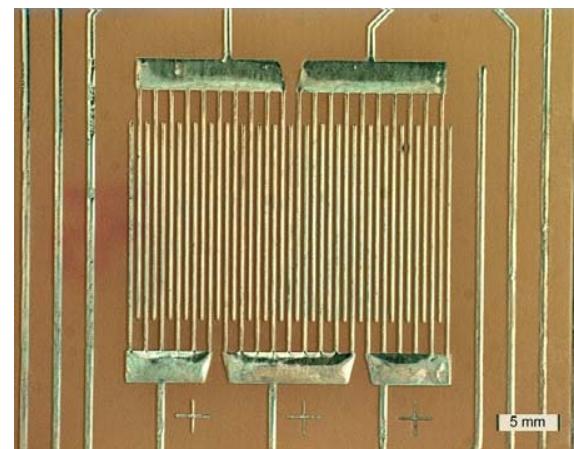
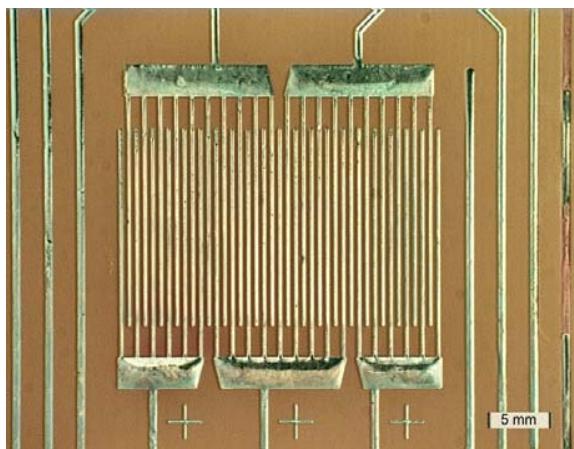
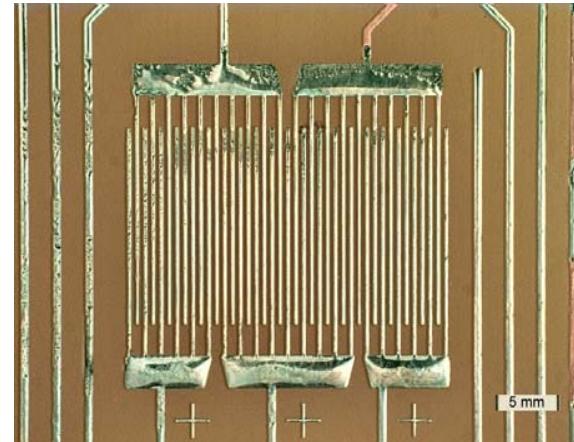
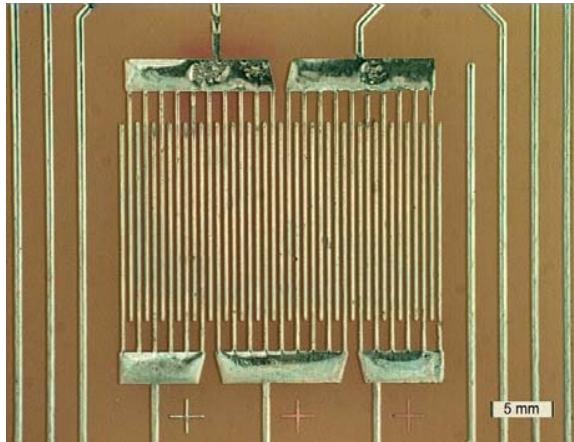
Run #2 EMR Test Results (Cont.)



Sn 63/Kester 244, reflow solder - shiny solder black dendrites, bare copper comb edge, shorted?

 BOEING

Run #2 EMR Test Results (Cont.)



Tin Silver Copper, Wave - small black dendrites not as shiny as tin lead

Electromigration test observations/recommendations

- **Tin lead samples (wave and reflow)**
 - Samples in both wave and reflow solder had dendritic growth and dendrites across multiple traces
- **Tin silver copper bismuth (reflow)**
 - Black corrosion observed as well as a residual binder material between the traces but no dendritic growth
 - Wettability was the poorest of materials tested
 - **Not a good choice for a lead free alloy**
- **Tin Copper wave**
- **Black corrosion and white dendrites observed**
- **Tin silver copper (wave and reflow)**
 - Best lead-free alloy tested
 - Smallest dendrites

Surface Insulation Resistance (SIR) Test Results

- SIR Testing (85/85 conditions)

Samples	Material/condition									
	Sn Ag Cu		SnAgCuBi		Sn Pb		Sn Cu		None (copper only)	
	Reflow	Wave	Reflow	Wave	Reflow	Wave	Reflow	Wave	Reflow	Wave
SAC 1 - 6	X									
SACU 1 - 6		X								
SACB 1 - 6			X							
SCU 1 - 6								X		
Sn Pb 1 - 6					X					
1W - 6W						X				
Cu 1 - 6									No bake*	
Cont 1 - 6									Bake*	

* - Reflow/wave condition not applicable.

Surface Insulation Resistance (SIR) Test Results

- **Tray 1 test results**

Solder/Process*	Tray/Batch	Serial Number	Surface Insulation Resistance (Ohms)			
			Initial	72 Hours	120 Hours	168 Hours
Cu Control (No Bake)/None	1/1	4A	1.2×10^{13}	4.5×10^{11}	1.2×10^{12}	8.0×10^{11}
		4B	2.1×10^{11}	2.1×10^9	2.8×10^9	5.9×10^9
		4C	2.0×10^{11}	2.8×10^9	6.2×10^8	1.5×10^9
		4D	2.1×10^{11}	4.3×10^9	5.8×10^9	5.5×10^9
		5A	2.0×10^{11}	4.5×10^{11}	3.0×10^{12}	8.0×10^{11}
		5B	2.0×10^{11}	4.5×10^{11}	5.5×10^{11}	8.0×10^{11}
		5C	2.4×10^{12}	4.0×10^{11}	5.5×10^{11}	1.0×10^{12}
		5D	2.8×10^{11}	6.0×10^{11}	5.5×10^{11}	1.0×10^{12}
SAC/Wave	1/1	1A	2.1×10^{11}	3.2×10^9	4.2×10^9	1.8×10^9
		1B	2.1×10^{11}	2.1×10^9	2.8×10^9	5.9×10^9
		1C	2.0×10^{11}	2.8×10^9	6.2×10^8	1.5×10^9
		1D	2.1×10^{11}	4.3×10^9	5.8×10^9	5.5×10^9
		2A	5.2×10^{12}	1.1×10^{11}	1.8×10^{11}	2.8×10^{11}
		2B	7.2×10^{12}	9.5×10^{10}	1.4×10^{11}	2.0×10^{11}
		2C	1.8×10^{11}	4.5×10^{11}	6.5×10^{11}	1.0×10^{11}
		2D	5.2×10^{10}	1.4×10^{11}	1.5×10^{12}	4.0×10^{11}

* Wave or Reflow (solder only)

Surface Insulation Resistance (SIR) Test Results

- Tray 1 test results (Cont.)

Solder/Process*	Tray/Batch	Serial Number	Surface Insulation Resistance (Ohms)			
			Initial	72 Hours	120 Hours	168 Hours
Cu Control (No Bake)/None	2/1	1A	6.0×10^{12}	1.0×10^{12}	1.2×10^{12}	6.5×10^{11}
		1B	5.0×10^{10}	9.0×10^{11}	1.2×10^{12}	1.5×10^{12}
		1C	2.0×10^{13}	1.0×10^{14}	2.0×10^{13}	3.0×10^{13}
		1D	2.0×10^{13}	1.0×10^{13}	3.0×10^{13}	2.0×10^{13}
		2A	1.4×10^{13}	6.0×10^{11}	9.0×10^{11}	1.0×10^{12}
		2B	1.0×10^{13}	5.5×10^{11}	7.5×10^{11}	1.0×10^{12}
		2C	1.1×10^{11}	6.0×10^{11}	9.0×10^{12}	4.0×10^{12}
		2D	1.4×10^{11}	5.5×10^{11}	3.0×10^{12}	5.0×10^{12}
		3A	2.0×10^{12}	5.5×10^{11}	7.0×10^{11}	1.5×10^{12}
		3B	2.0×10^{12}	4.5×10^{11}	1.2×10^{11}	4.5×10^{12}
		3C	5.5×10^{12}	4.5×10^{11}	1.1×10^{11}	1.5×10^{12}
		3D	2.0×10^{12}	5.0×10^{11}	1.2×10^{12}	1.5×10^{12}
Copper Control (Baked)/None	2/1	4A	1.1×10^{13}	9.0×10^{11}	8.0×10^{11}	1.0×10^{12}
		4B	1.1×10^{13}	9.0×10^{11}	7.5×10^{12}	1.0×10^{12}
		4C	7.5×10^{10}	7.0×10^{12}	5.0×10^{12}	1.0×10^{12}
		4D	1.9×10^{11}	8.0×10^{12}	6.0×10^{12}	1.0×10^{12}

* Wave or Reflow (solder only)

Surface Insulation Resistance (SIR) Test Results

- Tray 1 test results (Cont.)

Solder/Process*	Tray/Batch	Serial Number	Surface Insulation Resistance (Ohms)			
			Initial	72 Hours	120 Hours	168 Hours
SAC/Wave	3/1	3A	7.5×10^{12}	1.7×10^{11}	3.2×10^{12}	5.0×10^{11}
		3B	1.4×10^{13}	2.4×10^{11}	4.5×10^{11}	6.5×10^{11}
		3C	9.5×10^{10}	2.6×10^{11}	4.5×10^{11}	6.5×10^{11}
		3D	1.3×10^{11}	2.4×10^{11}	4.5×10^{11}	7.0×10^{11}
		4A	4.8×10^{10}	2.2×10^{11}	3.0×10^{12}	3.6×10^{12}
		4B	7.0×10^{10}	2.5×10^{11}	4.0×10^{12}	4.0×10^{12}
		4C	7.0×10^{12}	2.8×10^{11}	6.0×10^{11}	8.0×10^{11}
		4D	1.2×10^{13}	2.8×10^{11}	5.5×10^{11}	8.0×10^{11}
		5A	6.0×10^{12}	3.0×10^{11}	6.0×10^{11}	8.0×10^{11}
		5B	1.0×10^{13}	3.0×10^{11}	6.0×10^{11}	8.5×10^{11}
		5C	1.0×10^{11}	2.2×10^{11}	3.0×10^{12}	6.0×10^{11}
		5D	1.1×10^{11}	3.1×10^{11}	3.5×10^{12}	6.0×10^{11}
		6A	1.0×10^{13}	9.0×10^{11}	1.1×10^{12}	1.5×10^{11}
		6B	1.4×10^{13}	1.0×10^{12}	1.2×10^{12}	1.5×10^{11}
		6C	4.2×10^{10}	8.0×10^{10}	4.0×10^{12}	1.6×10^{11}
		6D	4.0×10^{11}	5.5×10^{11}	1.0×10^{13}	5.5×10^{11}
Copper Control (Baked)/None	4/1	1A	1.4×10^{12}	7.0×10^{11}	8.0×10^{11}	9.0×10^{11}
		1B	1.2×10^{12}	6.0×10^{11}	7.0×10^{11}	5.5×10^{12}
		1C	5.5×10^{11}	6.5×10^{11}	7.0×10^{11}	4.0×10^{12}
		1D	5.2×10^{11}	6.5×10^{11}	7.0×10^{11}	4.0×10^{12}
		2A	2.0×10^{13}	5.0×10^{11}	6.5×10^{11}	1.0×10^{12}
		2B	2.0×10^{13}	4.0×10^{11}	7.0×10^{11}	9.0×10^{11}
		2C	2.6×10^{12}	4.5×10^{11}	7.5×10^{11}	9.0×10^{11}
		2D	1.4×10^{12}	6.5×10^{11}	7.5×10^{11}	9.0×10^{11}
		3A	1.2×10^{13}	6.0×10^{11}	7.5×10^{11}	8.5×10^{11}
		3B	1.2×10^{13}	7.0×10^{11}	7.5×10^{11}	9.0×10^{11}
		3C	2.6×10^{12}	6.0×10^{11}	7.5×10^{11}	1.0×10^{12}
		3D	7.0×10^{11}	6.0×10^{11}	6.5×10^{11}	9.0×10^{11}
		5A	1.2×10^{13}	6.5×10^{11}	9.0×10^{11}	1.0×10^{12}
		5B	1.2×10^{13}	6.5×10^{11}	7.5×10^{11}	1.0×10^{12}
		5C	3.6×10^{12}	7.0×10^{11}	7.5×10^{11}	9.0×10^{11}
		5D	2.0×10^{12}	6.5×10^{11}	8.0×10^{11}	9.0×10^{11}

* Wave or Reflow (solder only)



Surface Insulation Resistance (SIR) Test Results

- Tray 2 test results

Solder/Process*	Tray/Batch	Serial Number	Surface Insulation Resistance (Ohms)			
			Initial	72 Hours	120 Hours	168 Hours
SAC/Wave	1/2	1A	9.0×10^{13}	1.2×10^{10}	1.6×10^{10}	2.1×10^{10}
		1B	5.0×10^{13}	4.0×10^{11}	1.8×10^{10}	2.2×10^{10}
		1C	5.0×10^{13}	5.4×10^{10}	1.6×10^{11}	2.2×10^{10}
		1D	5.0×10^{13}	5.2×10^{11}	1.3×10^{11}	2.4×10^{10}
		2A	4.0×10^{13}	1.4×10^{10}	2.2×10^{10}	2.3×10^{10}
		2B	1.3×10^{13}	1.8×10^{10}	2.4×10^{11}	2.2×10^{10}
		2C	5.0×10^{13}	1.6×10^{10}	2.1×10^{11}	2.4×10^{10}
		2D	5.0×10^{13}	1.3×10^{10}	1.9×10^{10}	2.6×10^{10}
		3A	5.0×10^{13}	1.6×10^{10}	2.1×10^{11}	2.2×10^{10}
		3B	5.0×10^{13}	1.3×10^{10}	1.9×10^{10}	2.2×10^{10}
		3C	5.0×10^{13}	1.4×10^{10}	2.0×10^{10}	2.6×10^{10}
		3D	5.0×10^{13}	1.5×10^{10}	2.4×10^{11}	5.0×10^{10}
		4A	5.0×10^{13}	1.3×10^{10}	1.5×10^{10}	1.4×10^{10}
		4B	5.0×10^{13}	1.1×10^{10}	2.2×10^{10}	2.0×10^{10}
		4C	5.0×10^{13}	3.6×10^{10}	1.0×10^{12}	2.2×10^{10}
		4D	5.0×10^{13}	3.6×10^{10}	6.5×10^{11}	2.4×10^{10}
SAC/Reflow	2/2	5A	1.5×10^{13}	1.8×10^{10}	3.0×10^{10}	4.0×10^{10}
		5B	5.0×10^{13}	2.0×10^{10}	2.8×10^{10}	3.2×10^{10}
		5C	5.0×10^{13}	2.2×10^{10}	7.0×10^{10}	3.8×10^{10}
		5D	5.0×10^{13}	2.8×10^{10}	3.5×10^{11}	4.5×10^{10}
		6A	1.0×10^{13}	1.6×10^{10}	2.0×10^{10}	2.6×10^{10}
		6B	1.0×10^{13}	1.5×10^{10}	1.9×10^{10}	2.6×10^{10}
		6C	5.0×10^{13}	2.0×10^{10}	3.0×10^{11}	2.8×10^{10}
		6D	5.0×10^{13}	1.8×10^{10}	2.0×10^{11}	2.8×10^{10}
SNACB/Reflow		8A	5.0×10^{13}	1.1×10^{10}	1.6×10^{10}	1.5×10^{10}
		8	5.0×10^{13}	1.2×10^{10}	1.7×10^{10}	1.8×10^{10}
		8C	4.0×10^{13}	1.2×10^{10}	3.9×10^{11}	2.2×10^{10}
		8D	5.0×10^{13}	1.2×10^{10}	3.2×10^{11}	2.2×10^{10}
		11A	5.0×10^{13}	1.1×10^{10}	1.7×10^{10}	1.8×10^{10}
		11	3.0×10^{13}	1.1×10^{10}	1.6×10^{10}	1.8×10^{10}
		11C	3.0×10^{13}	9.5×10^{11}	3.9×10^{11}	1.6×10^{10}
		11D	3.0×10^{13}	1.2×10^{11}	3.8×10^{11}	1.8×10^{10}

* Wave or Reflow (solder only)



Surface Insulation Resistance (SIR) Test Results

- Tray 2 test results (Cont.)

Solder/Process*	Tray/Batch	Serial Number	Surface Insulation Resistance (Ohms)			
			Initial	72 Hours	120 Hours	168 Hours
SACB/Reflow	3/2	12A	1.5×10^{13}	5.2×10^9	8.5×10^{10}	1.0×10^{10}
		12B	2.0×10^{13}	8.0×10^9	1.0×10^{10}	1.2×10^{10}
		12C	5.0×10^{13}	1.4×10^{10}	1.5×10^{11}	2.2×10^{10}
		12D	5.0×10^{13}	1.2×10^{10}	1.4×10^{11}	2.2×10^{10}
		13A	4.0×10^{13}	1.1×10^{10}	8.0×10^9	6.5×10^9
		13B	5.0×10^{13}	1.8×10^{10}	2.2×10^{10}	2.1×10^{10}
		13C	1.2×10^{12}	1.1×10^{10}	2.6×10^{11}	1.7×10^{10}
		13D	5.0×10^{13}	7.0×10^9	2.0×10^{11}	1.3×10^{10}
		14A	2.0×10^{13}	1.3×10^{10}	2.2×10^{10}	2.4×10^{10}
		14B	2.0×10^{13}	1.3×10^{10}	1.8×10^{10}	2.4×10^{10}
		14C	2.0×10^{13}	1.3×10^{10}	3.2×10^{11}	2.2×10^{10}
		14D	2.0×10^{13}	1.5×10^{10}	2.8×10^{11}	2.8×10^{10}
		100A	3.2×10^{12}	5.3×10^9	6.0×10^9	7.0×10^9
		100B	1.5×10^{13}	7.0×10^9	8.5×10^9	9.0×10^9
		100C	2.0×10^{13}	9.5×10^9	8.5×10^9	1.5×10^{10}
		100D	2.0×10^{13}	9.0×10^8	1.5×10^9	5.5×10^9
SnPb/Wave	4/2	1 A	2.5×10^{13}	8.0×10^9	1.3×10^{10}	9.0×10^9
		1 B	2.5×10^{13}	8.0×10^9	1.3×10^{10}	1.4×10^{10}
		1 C	2.5×10^{13}	1.2×10^{10}	1.1×10^{10}	1.8×10^{10}
		1 D	2.5×10^{13}	1.1×10^{10}	1.1×10^{10}	1.7×10^{10}
		2 A	1.5×10^{13}	4.0×10^9	1.3×10^9	1.2×10^8
		2 B	1.5×10^{11}	4.0×10^9	1.3×10^9	1.2×10^8
		2 C	1.5×10^{11}	7.0×10^9	5.0×10^8	9.0×10^9
		2 D	1.5×10^{11}	6.0×10^9	5.0×10^7	1.0×10^8
		3 A	5.0×10^{13}	7.5×10^{10}	1.5×10^{11}	1.5×10^{11}
		3 B	5.0×10^{13}	1.2×10^{11}	2.8×10^{11}	2.2×10^{11}
		3 C	4.0×10^{13}	6.5×10^9	1.1×10^{10}	1.3×10^{10}
		3 D	2.0×10^{13}	6.5×10^9	1.3×10^{10}	1.3×10^{10}
		4 A	3.0×10^{13}	5.5×10^9	9.0×10^9	1.2×10^{10}
		4 B	3.0×10^{13}	5.5×10^9	8.5×10^9	1.1×10^{10}
		4 C	2.5×10^{13}	4.0×10^9	7.0×10^{10}	1.3×10^8
		4 D	2.5×10^{13}	2.2×10^9	3.2×10^{10}	1.2×10^{10}

* Wave or Reflow (solder only)

**Tin Silver
Copper
Bismuth
boards 11 and
13 showed
evidence of
dendritic
growth**

Surface Insulation Resistance (SIR) Test Results

- Tray 3 test results

Solder/Process	Tray/Batch	Serial Number	Surface Insulation Resistance (Ohms)			
			Initial	72 Hours	120 Hours	168 Hours
SnPb/Wave	1/3	5A	5.0×10^{12}	2.0×10^9	2.6×10^9	4.5×10^9
		5B	2.4×10^{12}	2.6×10^9	3.4×10^9	4.5×10^9
		5C	6.0×10^{12}	7.0×10^{10}	4.0×10^9	5.0×10^9
		5D	6.0×10^{12}	7.0×10^{10}	4.0×10^9	5.0×10^9
		6A	5.0×10^{12}	5.5×10^9	6.0×10^9	7.0×10^9
		6B	2.0×10^{13}	5.2×10^{10}	6.5×10^{10}	6.0×10^{10}
		6C	7.0×10^{12}	2.8×10^{11}	1.0×10^{10}	1.0×10^{10}
		6D	6.0×10^{12}	2.6×10^{11}	7.5×10^{10}	8.0×10^9
SnPb/Reflow	2/3	3A	7.0×10^{12}	1.5×10^9	1.4×10^9	2.6×10^9
		3B	3.8×10^{12}	4.0×10^9	3.0×10^9	3.4×10^9
		3C	5.0×10^{12}	5.0×10^9	2.8×10^{10}	4.5×10^9
		3D	6.0×10^{12}	3.4×10^9	2.8×10^{10}	3.8×10^9
		4A	6.0×10^{12}	7.0×10^9	5.5×10^9	5.5×10^9
		4B	6.0×10^{12}	1.0×10^{10}	7.5×10^{10}	5.5×10^9
		4C	6.0×10^{12}	6.0×10^{10}	8.0×10^9	2.1×10^{10}
		4D	6.0×10^{12}	6.0×10^{10}	6.0×10^9	3.2×10^9
		5A	6.0×10^{12}	4.0×10^9	3.2×10^9	1.6×10^9
		5B	7.0×10^{12}	4.5×10^9	2.4×10^9	2.2×10^9
		5C	6.0×10^{12}	3.1×10^{10}	2.4×10^9	1.6×10^9
		5D	6.0×10^{12}	3.4×10^{10}	2.4×10^9	1.4×10^9
		6A	1.0×10^{13}	1.7×10^{10}	1.2×10^{10}	1.4×10^9
		6B	1.0×10^{13}	1.1×10^{10}	8.0×10^9	1.1×10^{10}
		6C	9.0×10^{12}	1.1×10^{10}	1.0×10^{10}	1.4×10^{11}
		6D	9.0×10^{12}	1.8×10^{10}	1.4×10^{10}	1.0×10^{10}

* - 10X

• Tin/lead W4
board showed
evidence of
dendritic growth

Surface Insulation Resistance (SIR) Test Results

- Tray 3 test results (Cont.)

Solder/Process	Tray/Batch	Serial Number	Surface Insulation Resistance (Ohms)			
			Initial	72 Hours	120 Hours	168 Hours
Silver Copper/Wave	3/3	5A	6.0×10^{12}	1.3×10^{10}	6.50×10^9	4.5×10^9
		5B	7.0×10^{12}	4.5×10^{10}	3.0×10^9	2.4×10^{10}
		5C	4.0×10^{12}	7.0×10^9	5.5×10^9	3.6×10^9
		5D	5.0×10^{12}	3.8×10^{10}	3.2×10^{10}	2.2×10^{10}
		6A	6.0×10^{12}	1.5×10^{10}	1.4×10^{10}	1.1×10^{10}
		6B	8.0×10^{12}	1.0×10^{10}	8.5×10^9	7.5×10^9
		6C	6.0×10^{12}	1.0×10^{10}	9.0×10^9	7.5×10^9
		6D	7.0×10^{12}	1.6×10^{10}	1.5×10^{10}	1.5×10^{10}
		1A	7.0×10^{12}	8.0×10^{10}	9.0×10^9	6.0×10^9
		1B	6.0×10^{12}	5.5×10^9	7.0×10^9	5.5×10^9
Sn Pb/Reflow		1C	5.0×10^{12}	6.0×10^9	5.50×10^{10}	3.2×10^9
		1D	5.0×10^{12}	6.0×10^9	8.0×10^{10}	3.4×10^9
		2A	6.0×10^{12}	9.0×10^9	9.0×10^9	1.2×10^{10}
		2B	7.0×10^{12}	8.0×10^9	7.0×10^9	4.0×10^9
		2C	6.0×10^{12}	6.5×10^9	8.0×10^{10}	8.0×10^9
		2D	6.0×10^{12}	7.5×10^9	8.5×10^9	5.0×10^9
		1A	9.0×10^{12}	1.4×10^{10}	8.0×10^9	5.5×10^9
		1B	7.0×10^{12}	1.7×10^8	6.0×10^8	3.4×10^8
		1C	2.5×10^{12}	2.0×10^9	2.0×10^9	4.5×10^8
		1D	7.0×10^{12}	1.2×10^{10}	9.0×10^9	6.0×10^9
Sn Ag Cu/ Wave	4/3	2A	2.6×10^{13}	9.0×10^9	8.0×10^9	6.5×10^{10}
		2B	5.5×10^{12}	8.0×10^9	7.5×10^9	7.0×10^{10}
		2C	6.0×10^{12}	7.0×10^9	6.0×10^9	5.0×10^9
		2D	5.5×10^{12}	6.0×10^9	5.5×10^9	4.2×10^9
		3A	6.0×10^{12}	2.8×10^{10}	2.1×10^{10}	1.8×10^{10}
		3B	6.0×10^{12}	2.8×10^9	2.8×10^9	1.4×10^9
		3C	9.0×10^{12}	3.2×10^8	5.5×10^8	5.5×10^8
		3D	9.0×10^{12}	2.4×10^9	4.5×10^9	2.6×10^9
		4A	6.0×10^{12}	1.2×10^{10}	7.5×10^9	8.0×10^9
		4B	6.0×10^{12}	9.5×10^9	6.5×10^9	6.5×10^9
		4C	6.0×10^{12}	2.0×10^{11}	3.6×10^9	2.2×10^9
		4D	6.0×10^{13}	1.8×10^{11}	5.5×10^9	4.5×10^9

* - 10X

SIR Test Observations/Recommendations

- **Dendritic growth observed on three boards**
 - Tin Silver Copper Bismuth SABC 11 and SABC 13
 - Tin/lead W4
- **Lead-free candidates performed comparable to SnPb materials**

Sample	Tray/Batch	Average Surface Insulation Resistance (Ohms)			
		Initial	72 Hours	120 Hours	168 Hours
Copper control (no bake)	1/1	7.6×10^{12}	4.3×10^{11}	1.3×10^{12}	8.3×10^{11}
SAC/Wave	1/1	1.6×10^{12}	9.8×10^{10}	2.8×10^{11}	6.6×10^{11}
Cu control (no bake)	2/1	7.7×10^{12}	9.7×10^{12}	5.9×10^{12}	5.6×10^{12}
Copper control (bake)	2/1	1.2×10^{13}	8.3×10^{11}	1.1×10^{12}	2.3×10^{12}
Copper control (no bake)	2/1	1.2×10^{13}	8.3×10^{11}	1.1×10^{12}	2.3×10^{12}
SAC/Wave	3/1	5.1×10^{12}	3.5×10^{11}	2.3×10^{12}	1.5×10^{12}
Copper (no bake)	4/1	8.1×10^{13}	9.8×10^{12}	1.2×10^{13}	2.6×10^{13}
SAC/wave	1 / 2	4.6×10^{13}	7.1×10^{10}	1.8×10^{11}	2.3×10^{10}
SAC/reflow	2/2	3.6×10^{13}	2.0×10^{10}	2.1×10^{11}	3.3×10^{10}
SACB/reflow	2/2	4.1×10^{13}	1.1×10^{10}	1.9×10^{11}	1.8×10^{10}
SACB/reflow	3/2	2.7×10^{13}	1.0×10^{10}	9.1×10^{10}	1.61×10^{10}
Sn Pb/Wave	4/2	2.3×10^{13}	1.7×10^{10}	3.7×10^{10}	2.9×10^{10}
AgCu/Wave	1/3	7.2×10^{12}	9.3×10^{10}	2.1×10^{10}	1.3×10^{10}
Sn Pb/Reflow	2/3	6.8×10^{12}	1.8×10^{10}	1.3×10^{10}	1.4×10^{10}
AgCu/Wave	4/3	6.1×10^{12}	1.9×10^{10}	1.5×10^{10}	1.2×10^{10}
Sn Pb/Reflow	4/3	5.4×10^{12}	7.1×10^9	3.2×10^{10}	5.9×10^9
SnAgCu/Wave	4/3	1.2×10^{13}	3.1×10^{10}	6.2×10^9	1.3×10^{10}

Summary and Conclusions

- **Electromigration Resistance Testing**
 - Tin Silver Copper with 7100 GNR 360K flux performed the best in EMR testing
 - Alloy performed equally well in both wave and solder-reflow operations
- **SIR Testing**
 - Alloys performed comparable to Sn Pb materials in reflow and wave processes